E-MODULE ON PHYSIOLOGY OF RESPIRATION

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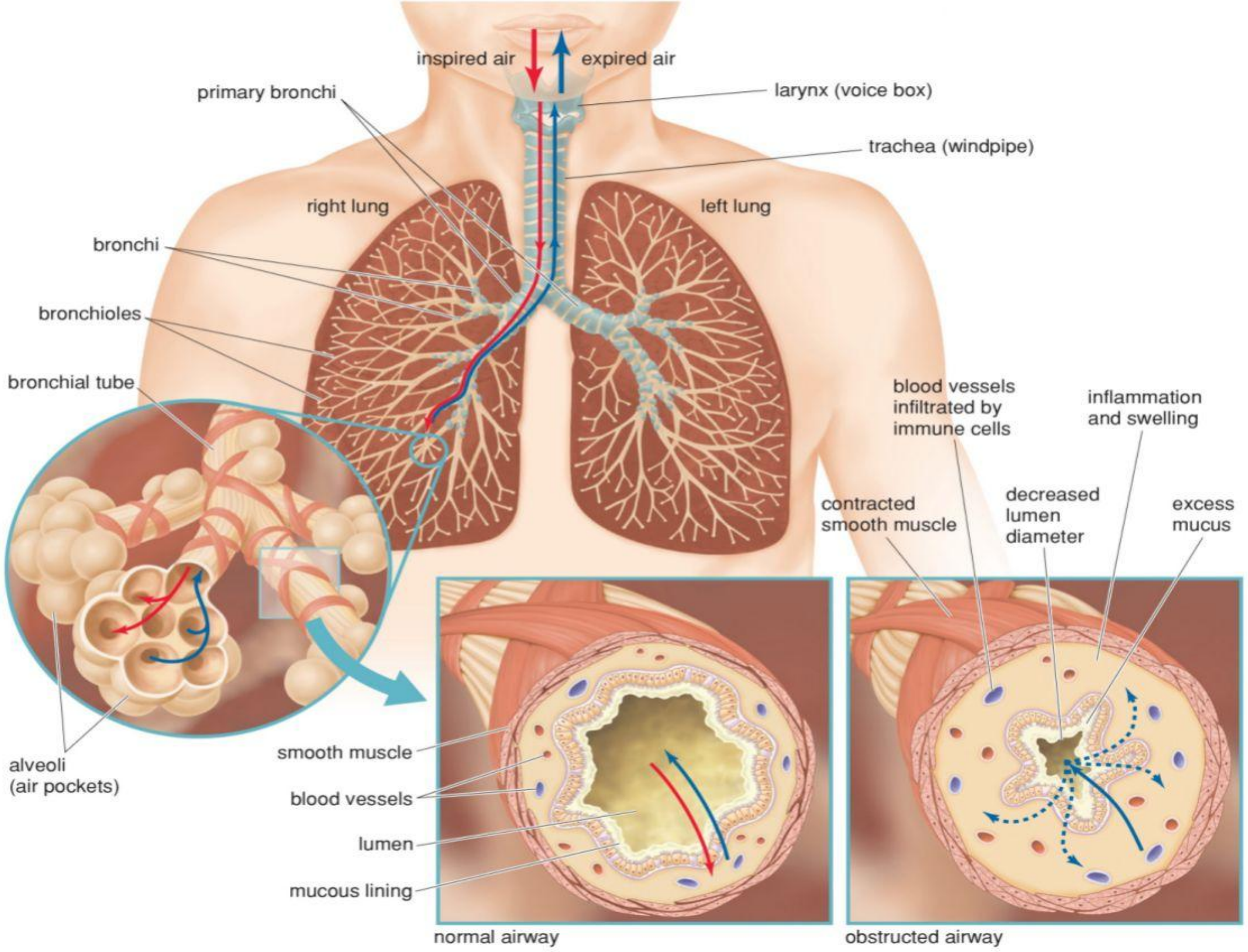
PHYSIOLOGY OF RESPIRATION



RESPIRATION

Respiration is the biochemical process in which the cells of an organism obtain energy by combining oxygen and glucose, resulting in the release of carbon dioxide, water, and **ATP** (the currency of energy in cells)

$$C_6H_{12}O_6 + 6O_2 \Rightarrow 6CO_2 + 6H_20 + ATP$$

Glucose Oxygen Carbon Dioxide Water Energy

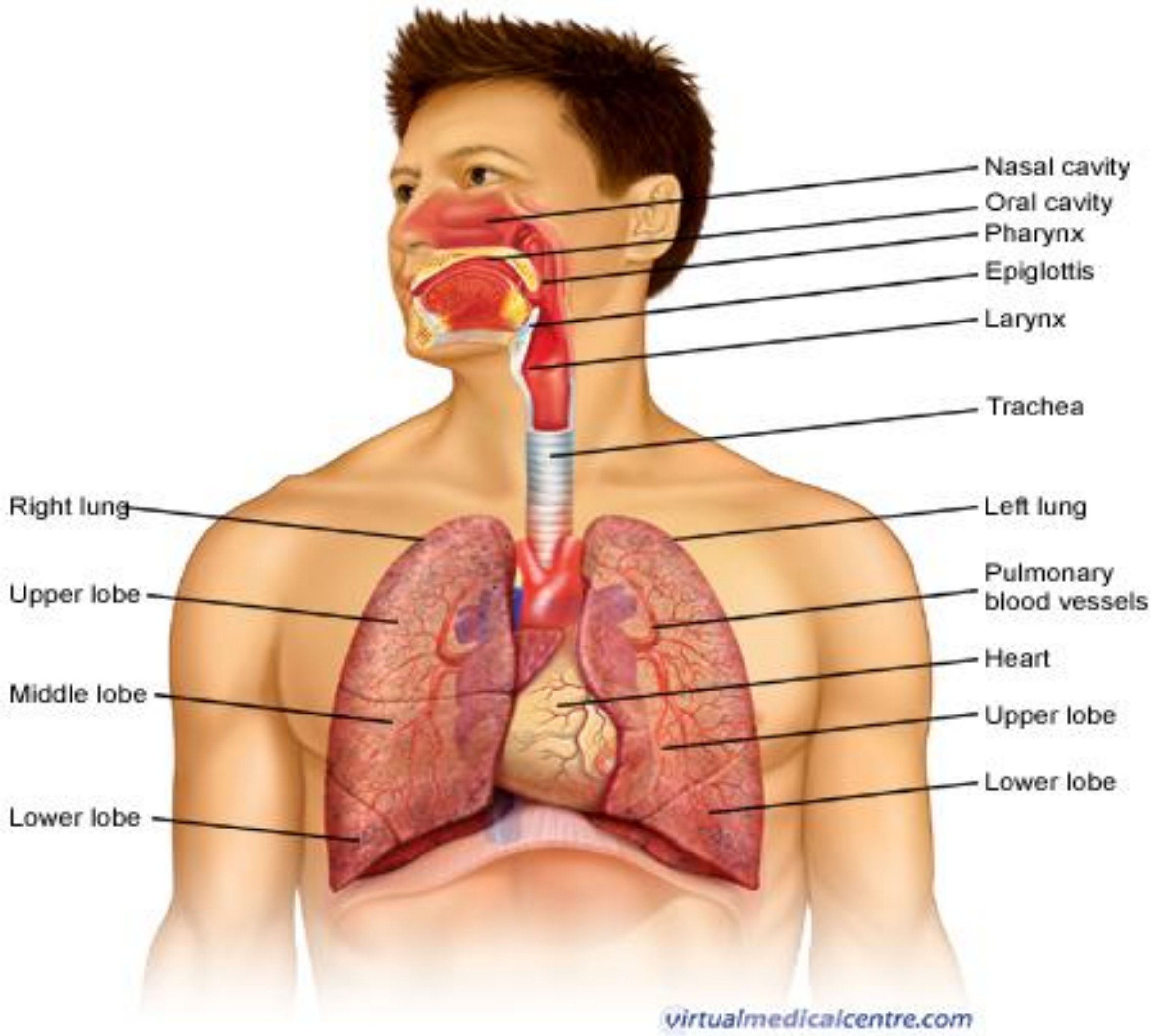
RESPIRATION

- The process in living organisms taking in oxygen from the surroundings and giving out carbon dioxide (**external respiration**).
- The chemical breakdown of complex organic substances, such as carbohydrates and fats, that takes place in the cells and tissues of animals and plants, during which energy is released and carbon dioxide produced(**internal respiration**)
- The function of respiration is to provide oxygen for use by body cells during cellular respiration and to eliminate carbon dioxide from the body.

RESPIRATION TYPES

- **Direct Respiration** is the exchange of environmental oxygen with carbon dioxide of body cells without the aid of blood.
- **Indirect Respiration** is the exchange of gases through respiratory organs through blood.
- **4 types of Respiration**
- Cutaneous
- Buccopharyngeal
- Branchial
- Pulmonary

PARTS OF RESPIRATORY SYSTEM



PARTS OF RESPIRATORY SYSTEM

RESPIRATORY TRACT

1External nares

2 Nasal chambers

3 Internal nares

4 Pharynx

5 Larynx

6 Trachea

RESPIRATORY ORGAN

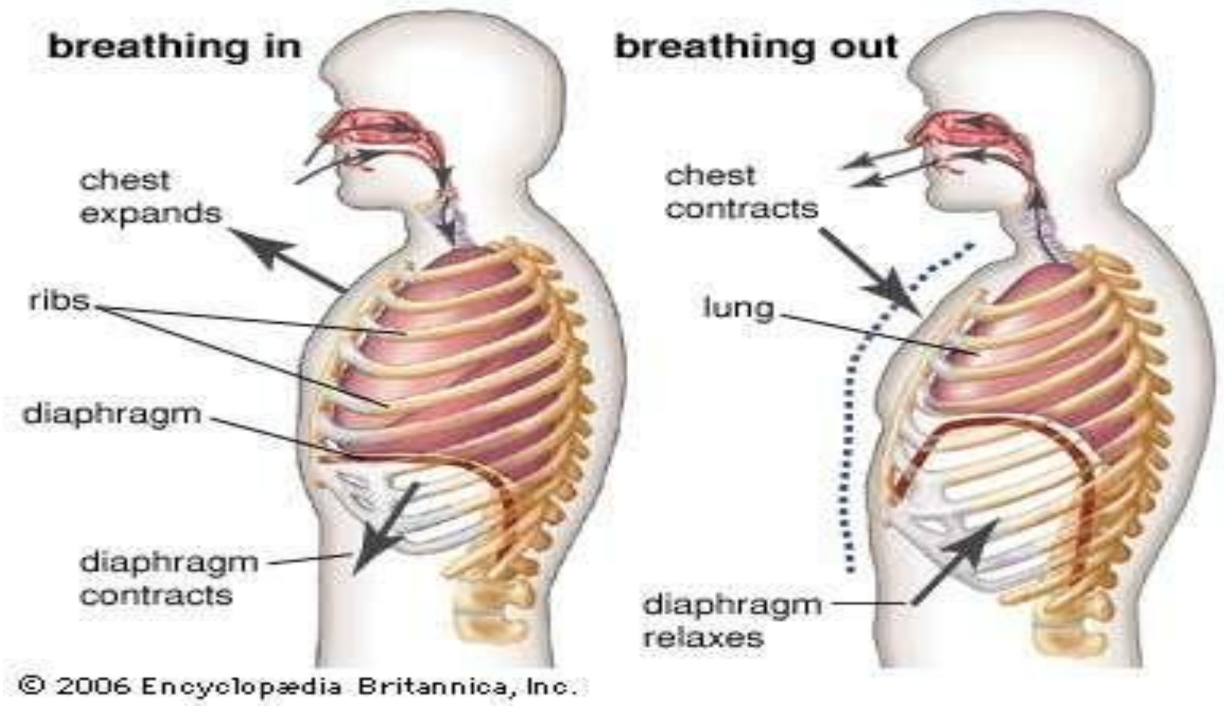
Lungs

MECHANISM OF RESPIRATION

- Breathing
- External respiration
- Internal respiration

BREATHING

Refers to movements which bring fresh air from air to lungs and remove foul air from lungs .



EXTERNAL RESPIRATION

- **External respiration** is defined as intake of oxygen by blood from air in lungs and elimination of CO_2 into air outside.
- It occurs as a function of partial pressure differences in oxygen and carbon dioxide between the alveoli and the blood in the pulmonary capillaries.
- Oxygen diffuses into the blood and carbon dioxide diffuses into alveolar air.

(**Partial pressure** is the pressure of a single type of gas in a mixture of gases).

INTERNAL RESPIRATION

Internal respiration or tissue refers to a metabolic process in which oxygen is released to tissues or living cells and carbon dioxide is absorbed by the blood.

Inside the cell the oxygen is used for producing energy in the form of ATP or adenosine triphosphate.

MECHANISM OF RESPIRATION

Inspiration is the the process of intake of air

- It takes place when the volume of thoracic cavity is increased and the air pressure is decreased and fresh air comes in respiratory tract.

Expiration is the elimination of foul air from body

- It takes place when the size of thoracic cavity is reduced and air pressure is increased and foul air goes out.

INSPIRATION

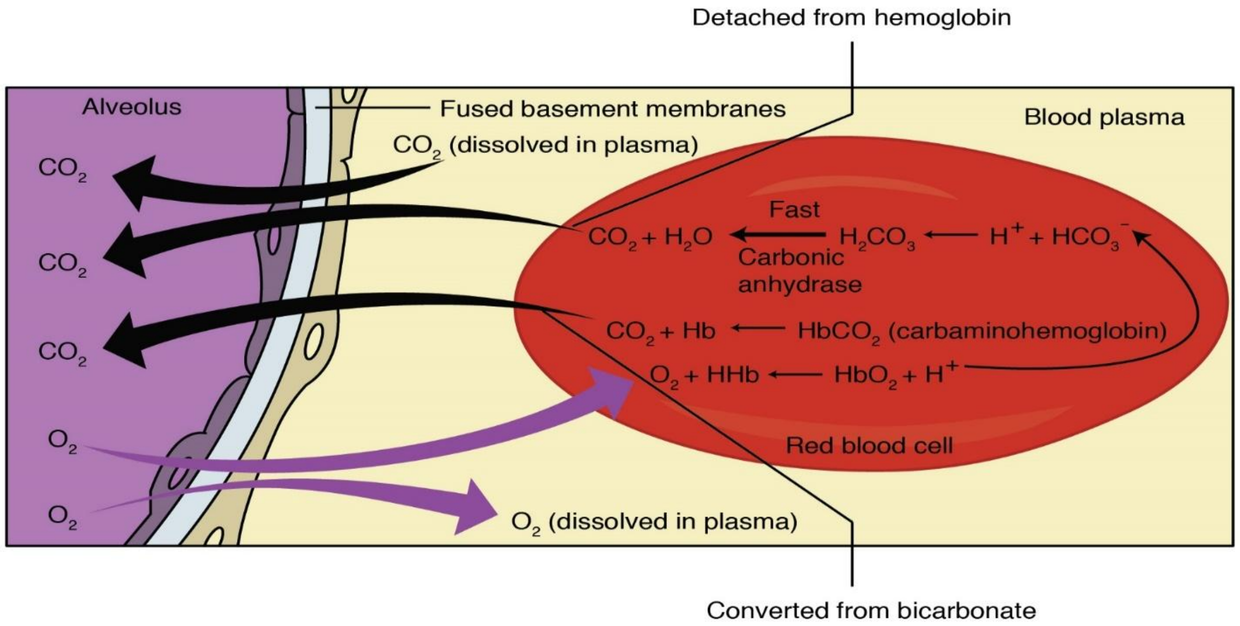
- First, external intercostal muscle contracts and internal intercostal muscles relaxes.
- Due to contraction of external intercostal muscles, ribs is pulled upward, resulting in increase in size of thoracic cavity .
- The thoracic cavity further enlarges due to contraction of diaphragm muscles lowering the diaphragm and increases the size of thoracic cavity further.
- With increase in size of thorax, lungs expand simultaneously.
- As lungs expands, the air pressure is reduced inside, so equalize the pressure, atmospheric air rushes inside the lungs

EXCHANGE OF GASES

Gas exchange occurs at two sites in the body:

1. In the lungs, where oxygen is picked up and carbon dioxide is released at the respiratory membrane.

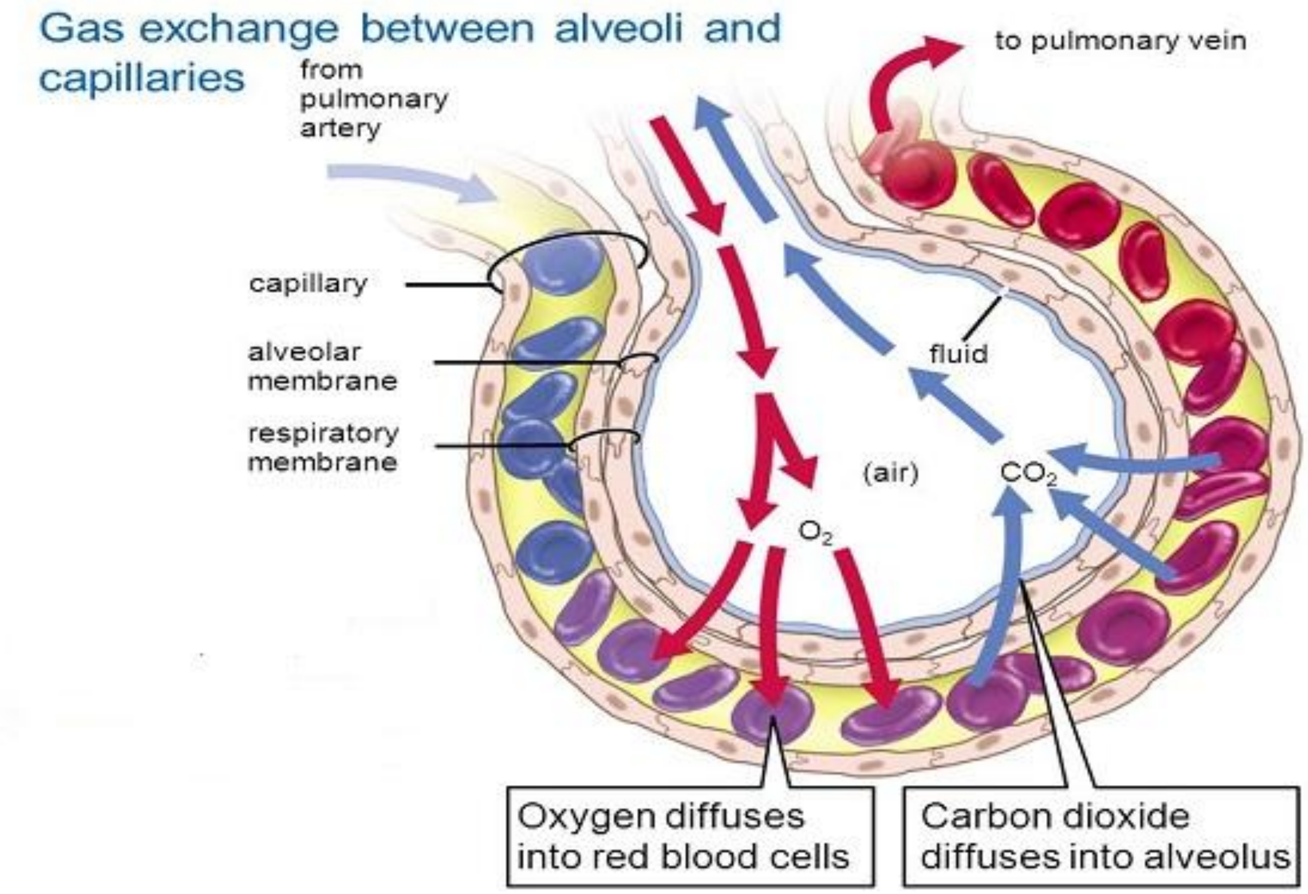
2. In the tissues, where oxygen is released and carbon dioxide is picked up.



EXCHANGE OF GASES

- **Gas exchange** is the delivery of oxygen from the lungs to the bloodstream, and the elimination of carbon dioxide from the bloodstream to the lungs.
- It occurs in the lungs between the alveoli and a network of tiny blood vessels called capillaries, which are located in the walls of the alveoli
- The actual exchange of gases occurs due to simple diffusion. Energy is not required to move oxygen or carbon dioxide across
- The respiratory membrane is highly permeable to gases; the respiratory and blood capillary membranes are very thin; and there is a large surface area throughout the lungs.

EXCHANGE OF GASES



EXPIRATION

- The internal intercoastal muscle contracts and external intercoastal muscles relaxes.
- Due to contraction of internal intercoastal muscle, ribs are pulled inward, resulting in decrease in size of thoracic cavity
- Furthermore the diaphragm is pushed upward due to its relaxation
- With the decrease in size of thoracic cavity, lungs is compressed
- As lungs is compressed, pressure increases, so the air is forced outside.

TRANSPORT OF GASES

- **Transport of oxygen in two forms**
- Oxygen is transported from lungs to the tissue in blood.
  Being soluble in water3% of total oxygen is carried as solution in plasma.
- About 97% of total oxygen is transported by RBC.
  which has a respiratory pigment hemoglobin which combines with oxygen to form oxyhemoglobin .
- Almost all oxygen are transported in this form, from lungs to tissue.

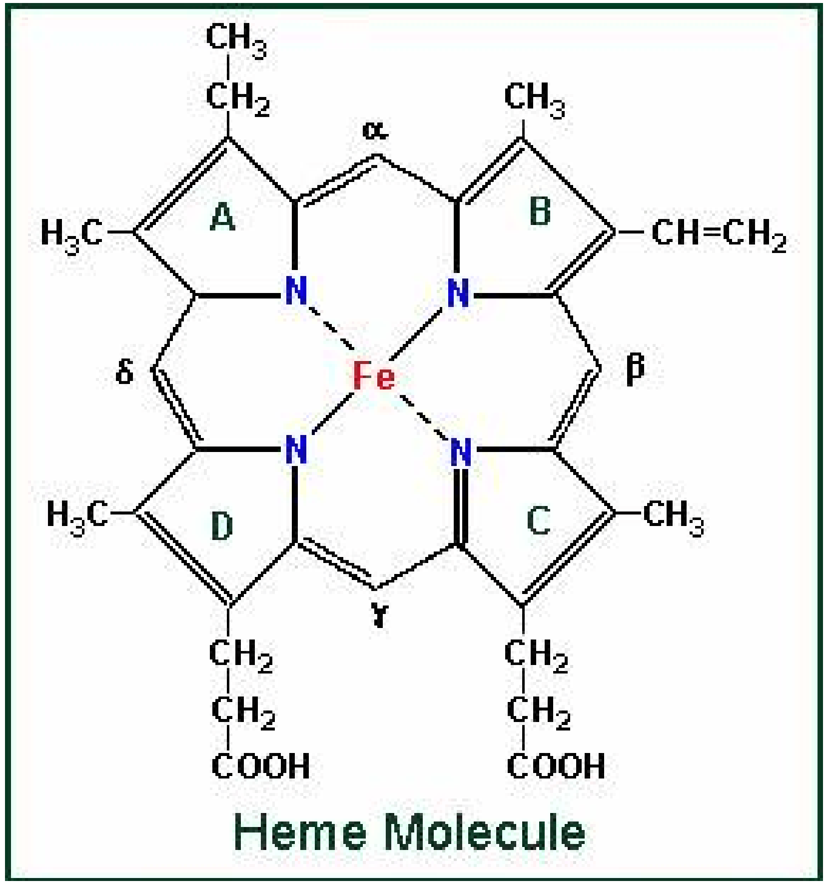
$$Hb_4 + 4O_2 \rightarrow Hb_4O_8$$

- Oxyhemoglobin compound is highly unstable compound and thus can dissociate quickly as it reaches to tissue.

HEMOGLOBIN

- **Hemoglobin**, or Hb, is a protein molecule found in red blood cells (erythrocytes) made of four subunits: two alpha subunits and two beta subunits (Figure 1). Each subunit surrounds a central **heme group** that contains iron and binds one oxygen molecule, allowing each hemoglobin molecule to bind four oxygen molecules.
- Molecules with more oxygen bound to the heme groups are brighter red. As a result, oxygenated arterial blood where the Hb is carrying four oxygen molecules is bright red, while venous blood that is deoxygenated is darker red.

HEMOGLOBIN STRUTURE



TRANSPORT OF GASES

i) Dissociation of oxyhemoglobin

As the oxyhemoglobin reaches to the tissue, it quickly dissociates into free oxygen and hemoglobin.

Oxygen enters into tissue, whereas the hemoglobin returns back to the RBC to pick up more oxygen.

$Hb_4O_8 \rightarrow Hb_4 + 4O_2$

TRANSPORT OF GASES

ii) Oxidation of food/ Tissue respiration

The oxygen oxidizes the glucose in presence of respiratory enzyme and releases energy, water and CO_2.

Energy is stored in the form of ATP in mitochondria to perform the metabolic activities

CO_2 is expelled from the tissue.

$C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{Energy}$

TRANSPORT OF CO2

- **Transportation of carbon dioxide**
- Carbon dioxide is the waste product which is produced in the body as a result of tissue respiration.
- Since CO_2 is very toxic, it is essential to remove out from the body. CO_2 is transported from tissue to lungs in following ways:

i) In form of physical solution

A very small amount of CO2 is dissolved in plasma and transported as solution.

TRANSPORT OF CO2

ii) In the form of carbonic acid

CO_2 combines with water of RBC to form carbonic acid. The process is catalyzed by an enzyme carbonic anhydrase found in RBC.

$CO_2 + H_2O$ carbonic anhydrase H_2CO_3 (carbonic acid)

TRANSPORT OF CO_2

iii) In the form of bicarbonates

About 70% of CO_2 are transported in this form.
Carbonic acid quickly ionizes to form ions i.e. bicarbonate and hydrogen ions.
Bicarbonates ions are pumped through RBC membrane into plasma.
Bicarbonates combines either sodium or potassium of plasma to form sodium bicarbonate or potassium bicarbonate respectively.
CO_2 is carried from tissue to the lungs through plasma.

Bicarbonates are carried through plasma to lungs where they combine with hydrogen ion and form water and carbon dioxide. The CO_2 is expelled out during expiration.

TRANSPORT OF CO_2

iv) In the form of carbamino hemoglobin compound

20-23% of CO_2 are transported in this form 20-23% of CO_2 are transported in this form.

CO_2 combines with amino group of haemoglobin to form a complex caramino hemoglobin compound

$CO_2 + HHb\text{-}NH_2 \rightarrow Hb\text{-}NH\text{-}COOH$

CO_2 produced in tissue are transported to lungs form where it is expelled out through expiration

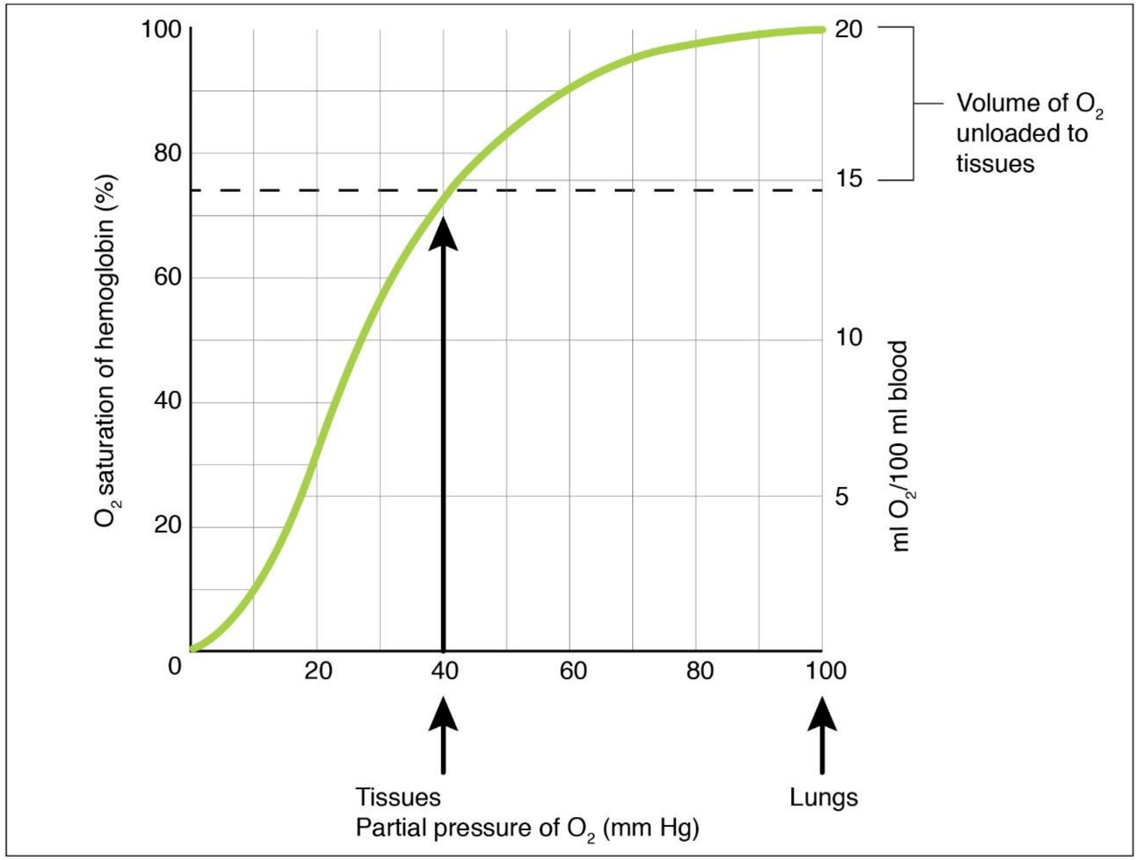
OXYGEN DISSOCIATION CURVE

- The graph of percentage of O_2 saturation of haemoglobin plotted against partial pressure of Oxygen (PO_2) is called **Oxygen dissociation curve.**
- The Oxygen dissociation curve is S-shaped (sigmoidal shape).
- The curve indicates that haemoglobin has high affinity to Oxygen.
- In human arterial blood have PO_2 of about 95-100 mmHg, at this level percentage of O_2 saturation of Hb is about 97 %. This indicates the formation of Oxyhaemoglobin is favored.
- Similarly, the venous blood have PO_2 of 40mmHg,at this level percentage of O_2 saturation of Hb is about 70%.

OXYGEN DISSOCIATION CURVE

- Once Hb saturation point is there very little additional binding occurs and the curve levels out.
- Hence the curve has a sigmoidal or S-shape.
- At pressures above about 60 mmHg, the standard dissociation curve is relatively flat, which means that the oxygen content of the blood does not change significantly even with large increases in the oxygen partial pressure

OXYGEN DISSOCIATION CURVE



(a) Partial pressure of oxygen and hemoglobin saturation

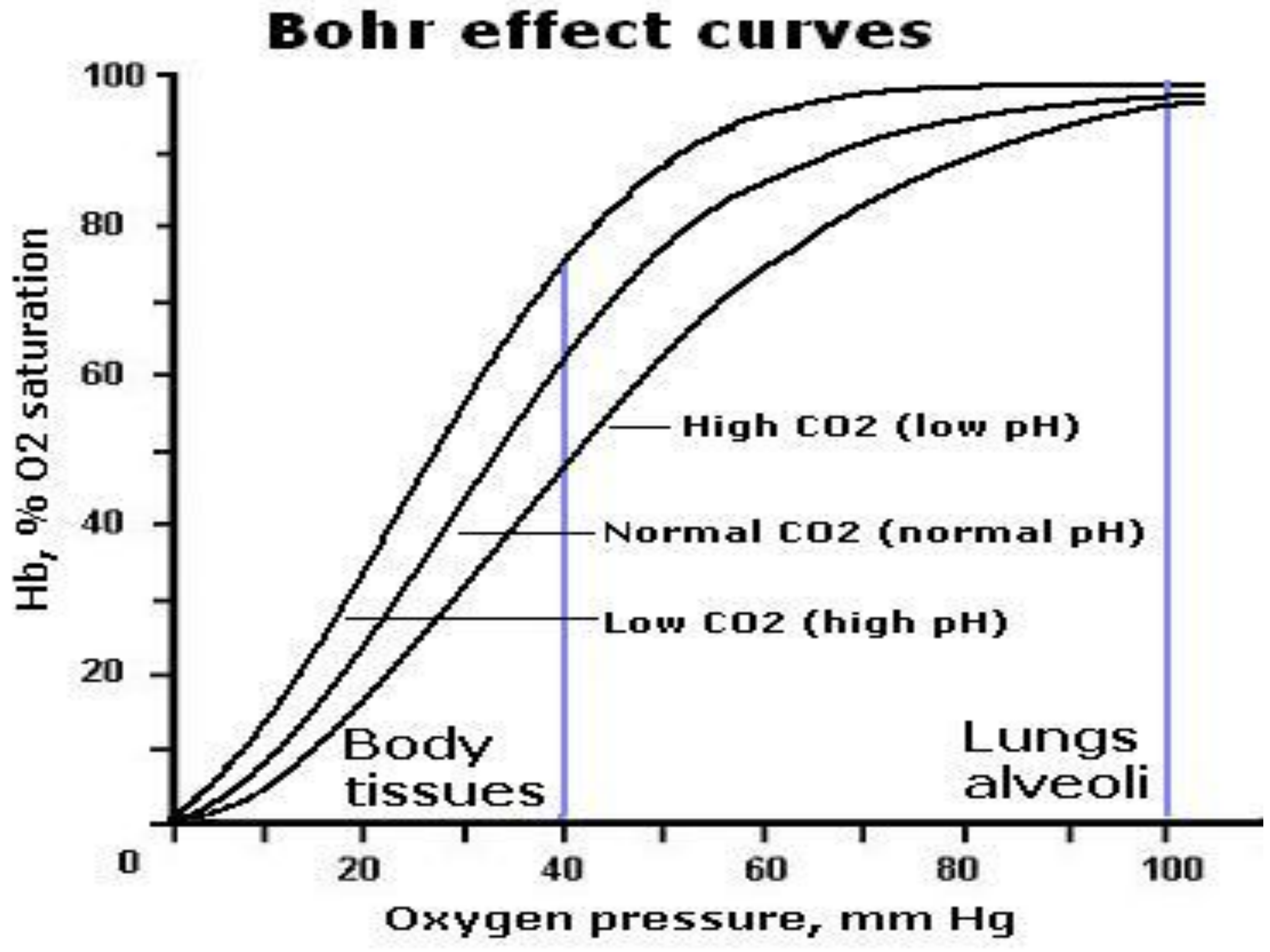
OXYGEN DISSOCIATION CURVE

- The strength with which oxygen binds to hemoglobin is affected by several factors and these change the shape the oxyhemoglobin dissociation curve.
- A rightward shift indicates that the hemoglobin has a decreased affinity for oxygen. This makes it more difficult for hemoglobin to bind to oxygen (requiring a higher partial pressure of oxygen to achieve the same oxygen saturation), but it makes it easier for the hemoglobin to release oxygen bound to it.
- The effect of this rightward shift of the curve increases the partial pressure of oxygen in the tissues during exercise, or hemorrhagic shock.
- The shifting of curve to left side indicates increased affinity for oxygen so that hemoglobin binds oxygen more easily, but unloads it more reluctantly. Left shift of the curve is a sign of hemoglobin's increased affinity for oxygen

BOHR EFFECT

- According to Bohr effect, for any particular partial pressure of Oxygen, the affinity of Haemoglobin toward Oxygen decreases and favors dissociation of oxyhaemoglobin when the partial pressure of carbon dioxide increases.
- It means, higher CO_2 concentration causes the dissociation of HbO_2 releasing free O_2.
- Increase in PCO_2 shifts the O_2 dissociation curve downwards. Higher PCO_2 lowers the affinity of haemoglobin for O_2.

BOHR EFFECT


Bohr effect curves
100
80
60
40
20
0
Hb, % O2 saturation
High CO2 (low pH)
Normal CO2 (normal pH)
Low CO2 (high pH)
Body tissues
Lungs alveoli
20
40
60
80
100
Oxygen pressure, mm Hg

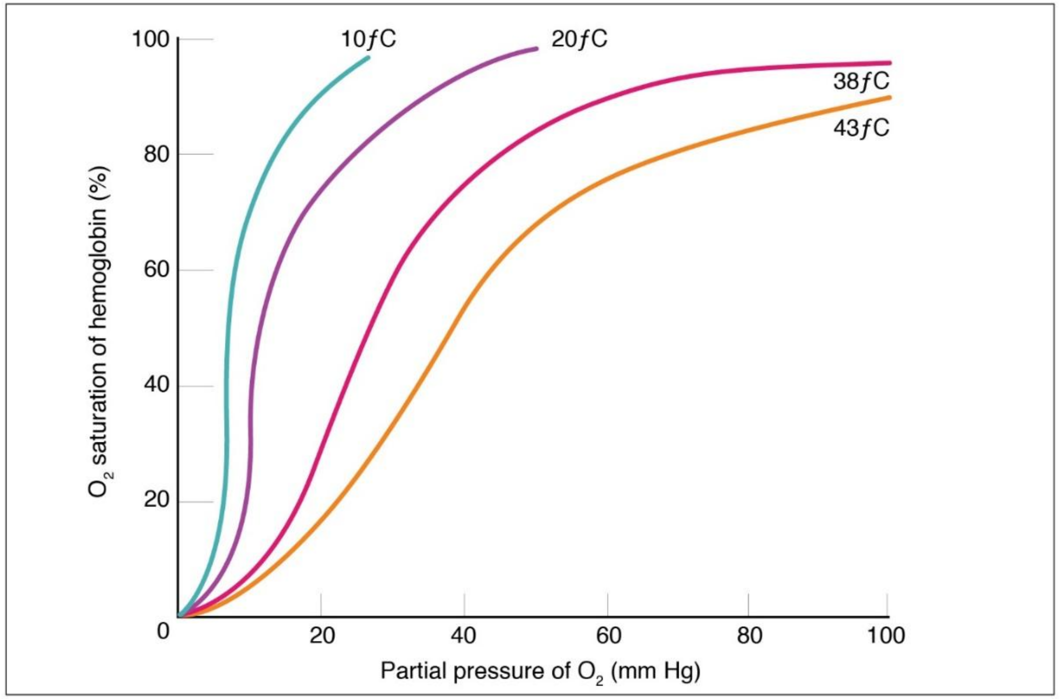
BOHR EFFECT

- Bohr effect is very important physiological phenomenon, because uptake of oxygen in lungs and its releases in the tissue is regulated by the concentration of CO_2 and H^+ ion as well as the partial pressure of O_2.
- PCO_2 is lower in lungs than tissue, so Hb has higher affinity for O_2, therefore it favors HbO_2 formation and transport of O_2 from lungs to tissue. similarly PCO_2 is higher in tissue, so it favors dissociation of HbO_2 releasing free O_2 and transport of CO_2 from tissue to lungs.

BOHR EFFECT

- A lower, more acidic pH promotes oxygen dissociation from hemoglobin. In contrast, a higher, or more basic, pH inhibits oxygen dissociation from hemoglobin.
- The greater the amount of carbon dioxide in the blood, the more molecules that must be converted, which in turn generates hydrogen ions and thus lowers blood pH.
- Furthermore, blood pH may become more acidic when certain byproducts of cell metabolism, such as lactic acid, carbonic acid, and carbon dioxide, are released into the bloodstream.

OXYGEN DISSOCIATION CURVE



(c) Effect of temperature

Oxygen-Hemoglobin Dissociation and Effects of pH and Temperature. These three graphs show (a) the relationship between the partial pressure of oxygen and hemoglobin saturation, (b) the effect of pH on the oxygen–hemoglobin dissociation curve, and (c) the effect of temperature on the oxygen–hemoglobin dissociation curve

HALDANE EFFECT

- The **Haldane effect** is a phenomenon that arises from the relationship between the partial pressure of oxygen and the affinity of hemoglobin for carbon dioxide.
- Hemoglobin that is saturated with oxygen does not readily bind carbon dioxide.
- However, when oxygen is not bound to heme and the partial pressure of oxygen is low, hemoglobin readily binds to carbon dioxide.

HALDANE EFFECT

- Deoxygenated hemoglobin has a higher affinity for CO_2 than does oxyhemoglobin.
- When hemoglobin is deoxygenated (i.e., at tissues) there is a right shift of the carbonic acid-bicarbonate buffer equation to produce H+ which increases the amount of CO_2 which is carried by the blood back to the lungs for exhalation.
- Therefore during oxygenation at the lungs CO_2 dissociates more radily from hemoglobin.

DIFFERENCE BETWEEN BOHR AND HALDANE EFFECT

- Bohr effect is the decrease of the oxygen binding capacity of haemoglobin with the increase of the concentration of carbon dioxide or decrease in pH whereas Haldane effect is the decrease of the carbon dioxide binding capacity of haemoglobin with the rise in the concentration of oxygen.
- Secondly, Bohr effect aids in the release of oxygen from oxyhemoglobin in tissues while Haldane effect aids in the release of carbon dioxide from carboxyhemoglobin in the lungs.
- Bohr and Haldane's effect are two properties of haemoglobin and help the dissociation of CO_2 and O_2 from the haemoglobin molecule.

CHLORIDE SHIFT(HAMBURGER SHIFT)

- **Chloride shift** is the diffusion of chloride ions from the plasma into the erythrocytes to compensate for the loss of bicarbonate ions from the cells as a result of carbon dioxide metabolism. It is also called Hamburger shift.

CHLORIDE SHIFT

1.When carbon dioxide enters the RBC from the tissue by simple diffusion it reacts with water in presence of carbonic anhydrase result in form the carbonic acid.

2.Carbonic acid breakdown in hydrogen H+ & bicarbonate ion(HCO_3^-).

3.Bicarbonate ion cross the RBC membrane by simple diffusion.

4.Thus inside the RBC develop a net positive charge. This positive charge neutralise by inward movement of negative chloride ion from plasma.

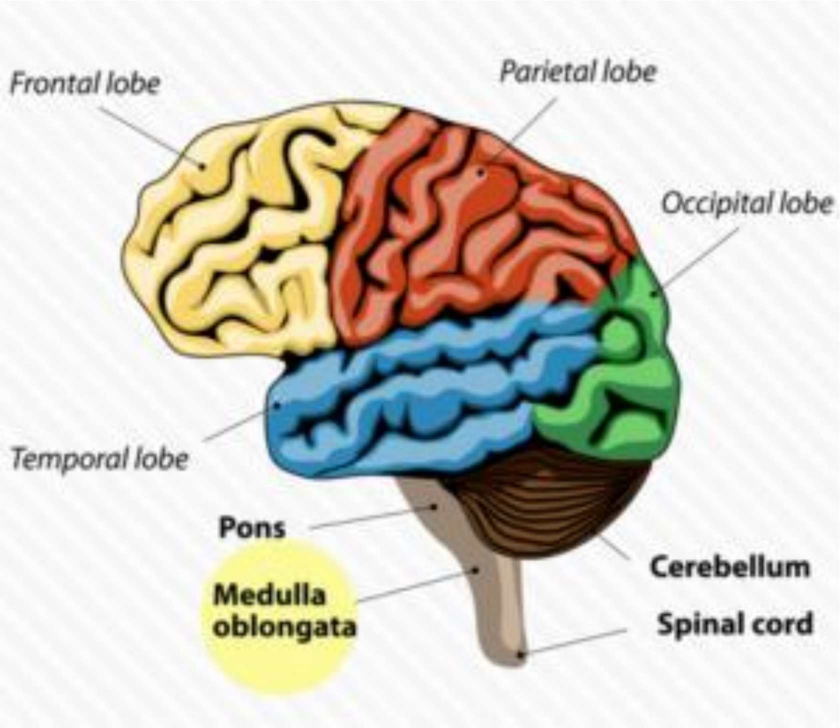
CONTROL OF RESPIRATION

- The respiratory centre is responsible for generating and maintaining the rhythm of respiration, and also of adjusting this in homeostatic response to physiological changes.
- The respiratory centre is located in the medulla oblongata and pons, in the brain.
- The respiratory centre is made up of three major respiratory groups of neurons, two in the medulla and one in the pons.
- In the medulla they are the dorsal respiratory group, and the ventral respiratory group.
- In the pons, the pontine respiratory group includes two areas known as the pneumotaxic centre and the apneustic centre.

CONTROL OF RESPIRATION

The respiratory center also receives input from

- Chemoreceptors in the brain
- Mechanoreceptors and stretch receptors in lung alveoli and bronchial tree.



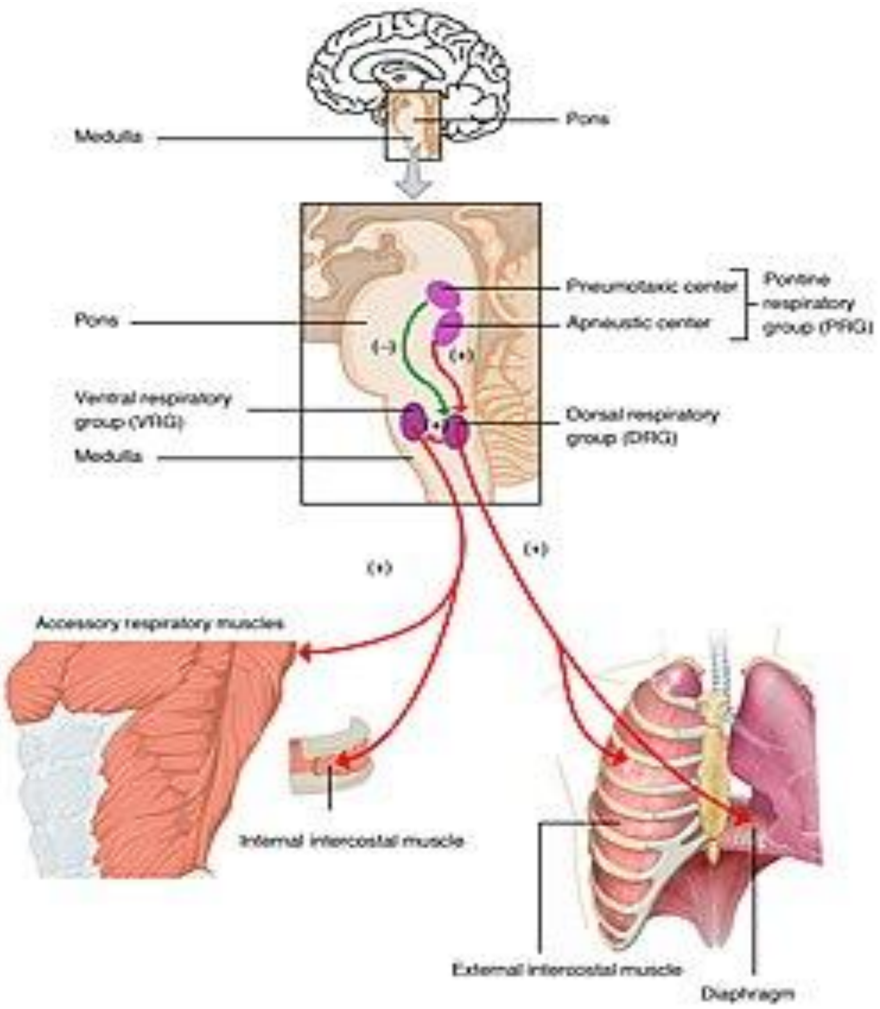
CONTROL OF BREATHING

- The medullary inspiratory centre, located in the medulla oblongata, generates rhythmic nerve impulses that stimulate contraction of the inspiratory muscles (diaphragm and external intercostal muscles).
- Normally, expiration occurs when these muscles relax, but when breathing is rapid, the inspiratory center facilitates expiration by stimulating the expiratory muscles (internal intercostal muscles and abdominal muscles).

CONTROL OF RESPIRATION

- The pheumotaxic area, located in the pons, inhibits the inspiratory centre, limiting the contraction of the inspiratory muscles, and preventing the lungs from overinflating.
- The apneustic area, also located in the pons, stimulates the inspiratory center, prolonging the contraction of inspiratory muscles.

RESPIRATORY CENTRES



CONTROL OF RESPIRATION

The respiratory centers are influenced by stimuli received from the following three groups of sensory neurons:

1.Central chemoreceptors (nerves of the central nervous system), located in the medulla oblongata, monitor the chemistry of cerebrospinal fluid.

- When CO_2 from the plasma enters the cerebrospinal fluid, it forms HCO_3^- and H^+, and the pH of the fluid becomes more acidic.
- In response to the decrease in pH, the central chemoreceptors stimulate the respiratory center to increase the inspiratory rate.

CONTROL OF RESPIRATION

2.Stretch receptors in the walls of bronchi and bronchioles are activated when the lungs expand to their physical limit.

- These receptors signal the respiratory center to discontinue stimulation of the inspiratory muscles, allowing expiration to begin. This response is called the inflation (Hering-Breur) reflex.

CONTROL OF RESPIRATION

3.Peripheral chemoreceptors (nerves of the peripheral nervous system) located in aortic bodies in the wall of the aortic arch and in carotid bodies in the walls of the carotid arteries monitor the chemistry of the blood.

- An increase in pH or PCO_2 or a decrease in PO_2 causes these receptors to stimulate the respiratory center.

REFRENCES

- www.google.com
- Text book of zoology P.S Dhami and J.K Dhami
- Modren's Zoology vol ii Biochemistry and Animal Physiology

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THANK YOU